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ADVANCE AMABILIS-FIR REGENERATION

IN THE VANCOUVER FOREST DISTRICT

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ABSTRACT

The growth characteristics of advance amabilis fir (Abies amabilis) beneath a mature overstory are discussed, and indicate that the age of advance growth cannot be predicted on the basis of stem size. Following overstory removal by commercial highlead logging, a delay of one full year was common before diameter growth response on the advance growth released from suppression. Height growth response, however, may be delayed for several years. Factors significant to the management of advance amabilis fir regeneration are described, including stem form, logging damage, stocking and density. The importance of suitable microsite and climate to growth response is suggested, although available data are inconclusive. The incidence of logging injuries ranged from 12 to 30%, of which the greatest proportion was stem wounds, such as scalps and gouges. The incidence of active decay infections associated with tree injuries was very low (1.8%) and was most common for advance growth stems of the largest size classes at the time of logging injury. The relationships of tree size and susceptibility to damage and decay are discussed. The method of attack by the Indian paint fungus (Echinodontium tinctorium) and its potential threat to advance amabilis fir regeneration are described. Survey results indicate little threat of decay by this fungus in advance growth less than 60 years of age at the time of release. Management prescriptions which will maximize growth and tree quality and minimize decay are briefly outlined.

RESUME

Les caractéristiques de croissance du Sapin gracieux (Abies amabilis) de régénération préexistante sous un étage dominant mature sont l'objet de la présente étude et l'auteur montre qu'il est impossible de prévoir l'âge des régénérations préexistantes en se foundant sur la grosseur de la tige. Suite à l'enlèvement de l'étage dominant au moyen de l'exploitation commerciale par câbles aériens (ou téléphérage relevé), on a noté fréquemment un délai d'une année complète avant de remarquer une hausse d'accroissement du diamètre chez les préexistants, libérés de la suppression. La réaction relative à la croissance en hauteur peut, cependant, se manifester après plusieurs années. L'auteur décrit les facteurs significatifs touchant l'aménagement d'une régénération de Sapins gracieux préexistants, y compris la forme de la tige, les dégâts causés par l'exploitation, aussi le matériel relatif et la densité. Il mentionne l'importance des microstations et du climat favorisant les réactions de croissance, bien que les données actuelles soient non concluantes. La fréquence des blessures dues à l'exploitation variait de 12 à 30 p. cent, dont la plus grande partie consistait en blessures de la tige, comme le dégazonnage et les cannelures ou stries. La fréquence des infections dues à la pourriture active, associée aux blessures d'arbres était très basse (1.8%) et fut la plus commune parmi les tiges des arbres préexistants classés les plus gros au moment de l'exploitation. L'auteur étudie la rapport entre la grossuer des arbres et la vulnérabilité aux dégâts et à la pourriture. Il décrit la méthode d'attaque par la carie brune filandreuse, Echinodontium tinctorium, et ses possibilités de menace à la régénération préexistante du Sapin gracieux. Les résultats de la recherche indiquent une légère menace de carie par ce champignon dans les peuplements préexistants âgés de moins de 60 ans au moment de leur libération. L'auteur souligne brièvement les moyens d'aménagement par lesquels on pourra obtenir au maximum de croissance et de qualité des arbres avec un minimum de pourriture.

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Introduction

E.P. 745 was initiated as a result of a recommendation made by the Reforestation Board in February 1974, for a study of the health, growth response, and suitability for regeneration purposes of advance amabilis fir at high elevations on the British Columbia coast. In April 1974, the Research Division (BCFS) and the Pacific Forest Research Centre (CFS) responded by launching a cooperative study to assess the suitability of advance amabilis fir as a restocking component following logging in the upper elevations of the Vancouver Forest District.

OBJECTIVES

1. To determine the growth response of advance amabilis fir (Abies amabilis (Dougl.)) regeneration following clearcutting, and to assess such factors as age, diameter, height and competition to determine their influence on growth response.

2. To determine the susceptibility of advance amabilis fir regeneration to attack by wound parasites after release and its susceptibility to the Indian paint fungus (Echinodontium tinctorium (Ell. & Ev.) Ell. & Ev.), and the significance of age and size at time of logging in relation to decay hazard.

INVESTIGATION METHODS

Following an initial inventory and selection of study areas, the project was conducted in two phases:

1. Field Measurement - field sampling was carried out on unburned clearcuts above 600 m elevation in the Vancouver Forest District. A systematic sampling along transects was carried out on each study area. Sample trees were measured and dissected to determine their age, height and diameter at the time logging took place, as well as currently. Other factors such as competition, stocking and density, and stem form were also assessed in the field. Basal disks were removed from each sample tree for accurate age counts and suppressed basal diameter measurement. A more complete description of each measured or assessed variable is as follows:

a) Height growth response (m) - the total height growth of the stem since the date of logging; or expressed as a mean annual response since logging.

b) Breast-height diameter growth response (cm) - the total outside-bark breast-height diameter growth since the date of

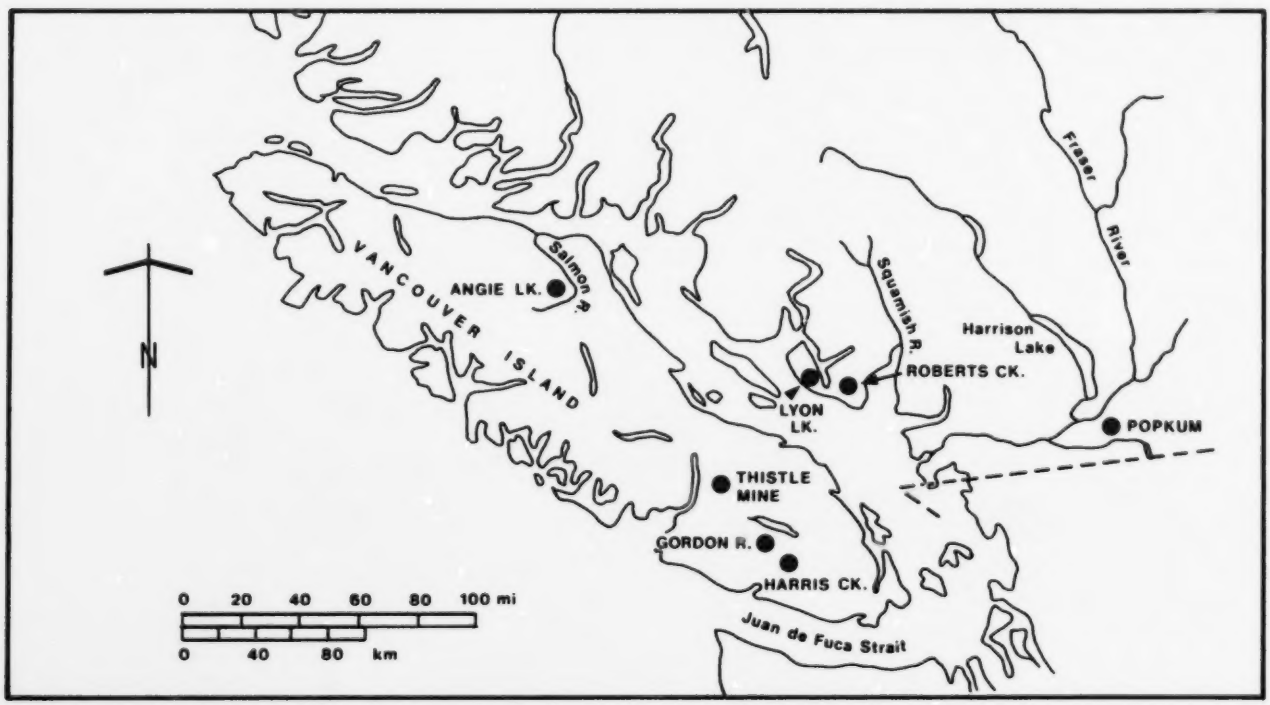

Fig. 1 Study area locations for the investigation of advance amabilis fir regeneration in the Vancouver Forest District.

logging; or expressed as a mean annual figure.

c) Basal diameter growth response (cm) - the total outside bark basal diameter growth since the date of logging; or expressed as a mean annual figure.

d) Height at release (m) - the height of the advance growth stem at the time logging of the overstory occurred.

e) Basal diameter at release - the inside-bark basal diameter of the stem at the time of logging.

f) Age at release (years) - age of the stem at the time of logging.

g) Response delay time (years) - the lag period from the date logging occurred until the first indication of accelerated radial growth response.

h) Frequency, size and condition of top and bole injuries - will be described under laboratory methods.

i) Presence of and severity of decay or stains - will be described under laboratory methods.

j) Stem Competition - expressed as the number of competing stems within a 2-m radius of the sample stem, as well as by a more subjective three class rating based on estimated crown and root competition.

k) Stem form - a subjective four class rating based on the shape of the bole and condition of the crown at the time of sampling.

2. **Laboratory Pathological Analyses** - in conjunction with the field survey, all scarred trees within sample plots were tallied to determine the incidence of logging damage in each study area. Scars were characterized as either "logging damage" or "frost injury", and classed as "closed" or "open" (healed or unhealed). Logging injuries were further characterized as either bole or top damage. All injuries were dissected in the field to determine the presence or absence of hidden defect (stain or decay). The extent of hidden defect was recorded as follows: trace = up to 5 cm; moderate = between 5 and 30 cm, and severe = greater than 30 cm in length. Stumps of all trees sampled were examined for the presence or absence of butt infections. Isolations were attempted in the laboratory from all wound samples with defect (stain or decay) to determine if decay fungi were involved and still viable.

Additional stem samples were taken in each study area in order to estimate susceptibility to the Indian paint fungus. Methods pertaining to cultural isolations and the study of the nature of the infection court were based on procedures developed previously for investigating the Indian paint fungus in western hemlock (Etheridge and Craig, in press).

Sampling was carried out on 11 study areas in seven general locations on Vancouver Island and the lower mainland (Fig. 1). Where any obvious site variation occurred within a study area, it was stratified into subareas for sampling. A site description of each study area is given in Appendix 1.

Results and Discussion

1. GROWTH CHARACTERISTICS

Table 1 provides sample means and their standard errors for the three variables that describe initial stem condition at the time of logging (height at release, basal diameter at release and age at release), and for the three variables describing growth following logging (mean annual height growth, basal diameter and breast-height diameter growth), tabulated for each study area. Heterogeneous variance, confirmed by Bartlett's test (Snedecor, 1956) for all variables, was accepted as real on acknowledging the numerous factors of site and stand history affecting development on individual areas. The standard errors of Table 1 are therefore derived from individual study area samples, rather than pooled samples, and all differences noted in the following discussion are significant on the basis of simple group comparisons and "t" tests. Appendix 2 presents significant simple within-area correlation coefficients among all variables investigated.

The data indicate considerable variation in the size and age of advance amabilis fir regeneration at the time of release within and between study areas. These results suggest the effect of stand type and history on the development of an advance amabilis fir understory. The successional status and species distribution of the overstory stand determines the extent of amabilis fir seed production within the stand, and hence the extent of understory seedling establishment. Schmidt (1957) indicated that the length of time after major forest fires determines the frequency of dominant amabilis fir in the overstories of coastal forests. Naturally, the longer that seed-producing amabilis fir are present in the overstory, the wider the range of ages of the advance regeneration, as illustrated by Harris Creek study area, where the oldest sampled advance growth stem was established in 1836 and the youngest was established in 1949, just 4 years before release in 1953. Other factors that affect seedling establishment in the understory are the types and moisture status of seedbeds, which are generally changeable in a mature forest, due to overstory damage caused by disease, insects and wind.

Once advance regeneration is established, the rate of suppressed growth varies considerably, even within the same site type. This fact is evidenced by the correlations between age and stem size at release in Appendix 2. The reasons for this are obvious. Variations in canopy cover and light intensity in the understory are common in mature stands. Also, variations in growing medium affect the growth rates of advance regeneration growing on them, as do variations in mutual competition. Examples of different suppressed growth rates within the same stand are easily found in the data. Two stems from the Harris Creek study area, for instance, were established in 1922 within 30 m of each other on similar microsites, but grew at significantly different rates. One stem reached 0.75 m in height by 1953, while the other reached only 0.34 m during the same period. Inspections of basal disks indicate that the rate of suppressed growth is also changeable, reflecting periodic changes in microsite and light intensity in the understory. While these occurrences are not surprising, they do indicate that the ages of advance amabilis fir cannot be accurately predicted by the size of the stem, even within the same stand.

Response delay, or the time delay interval between the date of logging and the first indication of accelerated radial growth was, on average, one full year after the year of logging. For instance, the majority of trees sampled from Angie Lake 2 study area responded in 1962, after release by logging in 1960. Although no substantial data exist, this delay is probably the result of gradual foliar adaptation to full sunlight conditions, as well as root system expansion. Kotar (1972) observed that amabilis fir seedlings growing in a forested environment under the reduced light conditions of the understory tend to have small root/shoot ratios. This phenomenon, common to many plant species growing under etiolated light conditions, appears to hold true for advance amabilis fir (Figure 2). It is relatively easy to uproot advance regeneration still under suppressed growing conditions, due to their small root systems. Before accelerated growth can be supported, expansion of this root system is necessary. Gordon (1973) reports similar diameter growth response delays for advance regeneration of red fir (Abies magnifica) and white fir (Abies concolor) in southern Oregon. He also cites other works by Hatcher (1964) and Bellon and Kowalski (1968) on balsam fir (Abies balsamea) and European silver fir (Abies alba), respectively. They report diameter growth responses for both species within 2 years after clearcutting, followed by height growth response after 3 years. Estimation of height growth response delays was not attempted in this project. It is likely, however, that significant height growth response is retarded longer than diameter growth response. Gordon (1973) reported significant height increases in red and white fir only after 4 to 5 years.

Response delay is a factor that must be considered in the early management of advance amabilis fir regeneration. Assessment of growth performance shortly after logging will not give a realistic indication of growth potential of the advance regeneration crop. Even after the initial growth increase, height will likely continue to accelerate over a number of years. These facts should be considered when decisions on post-logging treatment are being made. For instance, a decision to broadcast burn or scarify, which is made before the full growth potential of the advance amabilis fir regeneration is known, could well lead to unnecessary

Table 1. The mean and standard error of three initial state variables and three postlogging growth variables for advance amabilis fir regeneration sampled in 11 study areas in the Vancouver Forest District.

Study Area	Sample Size	Ht. at Release (m)		Basal D. at Release (cm)		Age at Release (yrs)		Mean Annual Height Growth (m)		Mean Annual Basal D. Growth (cm)		Mean Annual D.B.H. Growth (cm)	
		M	SE_m	M	SE_m	M	SE_m	M	SE_m	M	SE_m	M	SE_m
Gordon River 1	39	0.81	0.158	2.0	0.36	38	3.6	0.25	0.019	0.6	0.04	0.4	0.03
Gordon River 2	10	0.44	0.057	1.4	0.19	29	4.1	0.27	0.048	0.6	0.09	0.5	0.08
Harris Creek	111	0.72	0.047	1.8	0.09	48	2.0	0.21	0.009	0.4	0.02	0.4	0.01
Thistle Mine 1	72	0.36	0.030	1.1	0.09	30	2.2	0.19	0.008	0.5	0.02	0.1	0.02
Thistle Mine 2	60	0.75	0.048	1.9	0.12	39	1.9	0.31	0.012	0.6	0.03	0.5	0.02
Roberts Creek	66	0.79	0.077	1.9	0.14	44	2.6	0.40	0.008	0.8	0.03	0.7	0.02
Popkum 2	24	1.15	0.108	2.3	0.19	49	4.0	0.33	0.011	0.7	0.03	0.5	0.03
Popkum 1	29	1.58	0.217	3.2	0.32	60	4.4	0.35	0.012	0.8	0.05	0.7	0.03
Angie Lake 1	80	0.56	0.050	2.2	0.32	41	2.2	0.23	0.012	0.5	0.02	0.4	0.02
Angie Lake 2	144	0.65	0.071	1.5	0.12	40	2.4	0.22	0.007	0.6	0.02	0.4	0.01
Lyon Lake	68	0.62	0.073	1.7	0.20	49	5.0	0.27	0.010	0.7	0.03	0.4	0.03

Fig. 2 Illustrating the small root-shoot ratios of advance regeneration under suppressed growing conditions. The ages of the stems pictured above are, from left to right, 42 years, 68 years, 51 years, 38 years and 20 years of age.

restocking expense. In the same way, spacing or crop-tree selection carried out in a stand of advance regeneration before full-growth response may result in incorrect leave-tree selections to the detriment of the future amabilis fir crop.

Stem form of the advance amabilis fir regeneration ranged from class one stems with straight boles and well-developed crowns to class four stems with severe basal sweeps or crooks and small, poorly developed crown structure. Based on the total number of sampled stems, 64% were class one stems, 28% were class two stems with minor basal sweeps or crooks, while only 8% had more severe deformities that might cause utilization problems. While these data are based on observations made many years after logging, the more severe stem deformities are evidently a direct result of falling and yarding operations, where logs and branches have flattened or broken the advance regeneration stems. Minor stem sweeps (Fig. 3) appear to be a common characteristic of advance amabilis fir prior to release.

This deformity may be caused by snow-press, or snow and soil creep. The former assumption, given by Gordon (1973), appears more valid, since basal sweeps do not appear restricted only to trees growing on slopes. Most of the minor sweeps common at the time of release are promptly corrected by stem buttressing. This reaction tends to be the first accelerated radial growth response that an advance growth tree exhibits. Unlike the compression wood development of large trees, stem buttressing by advance regeneration will unlikely cause utilization problems after harvesting, since it occurs promptly and is followed by normal radial growth. Minor deformities are also inflicted on advance amabilis fir after release by leader damage or disease. Attack by Phomopsis lokoyae, a stem canker causing leader dieback, was relatively common in most of the sample areas. These attacks did not appear repetitive and resulted in only temporary reduction of height growth, causing slight stem crooks that were quickly outgrown. A summary of the findings on logging damage and other injuries will be subsequently discussed.

The overall stocking and density estimates for all study areas are given in Table 2.

Generally, the stocking of advance amabilis fir tended to be clumpy. Figure 4 illustrates typical non-stocked openings of variable size that were common where logging disturbance was severe, such as on highlead cable roads, or where advance regeneration had never been established. In many cases, brush invasion into these openings precluded postlogging natural regeneration. Advance amabilis fir stocking (by milacre quadrats) ranged from 12% in the Lyon Lake study area to 54% in the Thistle Mine 2 study area. Stand density varied from single, free-growing trees to dense clumps with overall density estimates of approximately 4000 stems per hectare (Fig. 5). The portion of total stocking contributed by other forms of regeneration, including advance western hemlock (Tsuga heterophylla) and postlogging naturals of amabilis fir and western hemlock, ranged from 31 to 60%. Most of this stocking was in the form of seedling and small sapling-size postlogging naturals.

Clearly, stocking and density levels of advance amabilis fir regeneration are far from being satisfactory, particularly where ground disturbance is severe. To attain adequate stocking standards, either fill-planting or assurance of adequate postlogging natural fill-in is required in non-stocked openings. In many cases, density control is also required to reduce clumpiness and mutual competition.

The rate of mean annual height growth response for the study areas ranged from 0.19 to 0.40 m (Table 1). These figures are conservative, however, since they do not consider response delay periods and tend to underestimate current annual growth rates. The relative growth rate increase after release on individual stems is considerable and needs little comment (Figs. 6 and 7). The wide range in growth response values in Table 1, however, requires explanation. Differences in mean annual growth rates exist between areas, and between subareas within several areas. In the case of subareas, site descriptions in Appendix 1 suggest that growth following release is affected by site quality, particularly moisture status. The advance regeneration sampled on the more moist and shaded subareas responded with higher mean annual growth rates than on the drier subareas. This trend can be seen in Table 3.

These results are not unusual, however, since the relatively high moisture requirements of amabilis fir are well known (Schmidt, 1957; Krajina, 1969; Kotar, 1972). Not only was growth response poor on the drier sites, but the advance amabilis fir regeneration often appeared unhealthy and suffering from moisture stress. This condition was evidenced by patchy, foliar necrosis, general chlorosis and stunted growth. These symptoms were more pronounced where competition was high.

Fig. 3 An advance amabilis fir 15 years after release, with a typical minor basal sweep. Tallyman is indicating the point of release (at 0.5 m) in 1960. The age at release of this stem was 30 years.

The variation in mean annual growth response rates between different study areas is difficult to attribute to site conditions, due to the wide range of site characteristics involved. Some of the differences indicated in Table 1, however, may not be due to differences in site quality and deserve mention.

The difference in the mean annual growth response between the two Thistle Mine study areas may partially be due to differences in the date of logging and the period of time that the trees on each area have had to respond to release. The advance regeneration on Thistle Mine 1 study area, released by clearcutting in 1967, has only recently begun to respond and may not have reached its full growth potential. The trees on Thistle Mine 2 study area have had a longer period in which to respond since release in 1964. This tends to weight the mean annual growth value in favor of the area with the longer period of release. In reality, the current growth rates of stems

Study area	Sample Size (milacre quadrats)	Advance amabilis fir Regeneration		All Regeneration Species	
		Stocking (%)	Density (stems/hectare)	Stocking (%)	Density (stems/hectare)
Gordon River 1 & 2	26	16	660	58	3720
Harris Creek	65	34	1600	75	4210
Thistle Mine 1	40	53	4000	84	8300
Thistle Mine 2	33	54	2600	84	6800
Roberts Creek	42	20	675	80	6000
Popkum 1 & 2	42	23	1300	73	3400
Angie Lake 1	37	29	1000	78	4920
Angie Lake 2	75	41	2428	74	6780
Lyon Lake	43	12	372	72	6370

Table 2. Stocking and density estimates (by milacre quadrats) of all study areas for advance amabilis fir regeneration, and for all regeneration species.

on Thistle Mine 1 study area appear to be equal to or greater than those of Thistle Mine 2 area. The same situation exists for the two Popkum study areas, where higher mean annual growth rates were recorded for advance growth on the older Popkum 1 clearcut.

When the above factor is considered, the only inference that can be drawn from a comparison of study area response growth rates is that the areas situated at the highest elevations, that is, the Popkum, Roberts Creek, Thistle Mine and Lyon Lake study areas, tend to exhibit greater mean annual response growth rates than the lowest elevation sites at Harris Creek and Gordon River. Studies by Kotar (1972) on the ecology of amabilis fir, indicate that site conditions, and especially soil moisture status, generally become more suitable for the growth of amabilis fir as elevation increases. Results from this project suggest this phenomenon, although they are too limited to be conclusive.

The correlation analysis results in Appendix 2 indicate that growth response, particularly diameter growth response, is related to stem competition following release and stem size at release. The strongest relationship appears to be between the growth variables and the degree of competition. The correlation coefficients of Appendix 2 show that growth response decreases with increasing competition. This is similar to the results of studies of subalpine fir (Abies lasiocarpa) by Stettler (1958) and Gordon (1973) on red and white fir. These results suggest that the high mutual competition common in clumpy advance amabilis fir regeneration will adversely affect growth performance and that stand treatment may be necessary to ensure optimum growth response.

Appendix 2 also shows that the larger the size of the advance growth stem at release, the greater the growth response. Gordon (1973) also found that advance regeneration of red and white fir with dominant crown positions at release continued to retain their relative dominance during growth response. Similar results were reported by Stettler (1958) for subalpine fir. The reason for these relationships appears, at least partly, due to the factor of competition; that is, the larger the stem, the less likely it is to suffer post-release suppression through competition. Stem size, however, holds particular significance regarding pathological risk and will be discussed later in this report.

A relatively strong relationship existed between age and size at release. The correlation coefficients were too small, however, to indicate a one-to-one relationship. This indicates that considerable differences exist in the degree of pre-logging suppression of advance regeneration, even in the same stand. As previously mentioned, variations over time in seedbed, microsite and overstory crown-cover probably account for this variation in suppressed growth rate. The data do suggest, however, that generally the oldest stems are the largest.

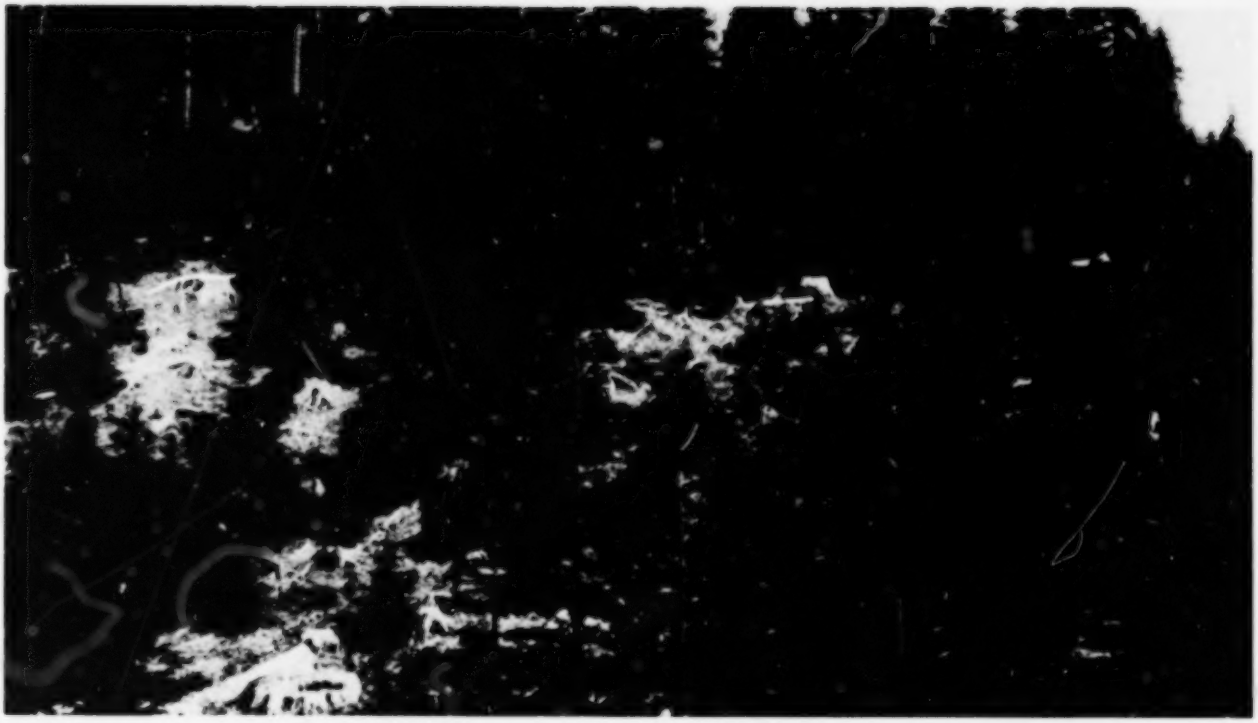

Fig. 4 A portion of the Angie Lake 2 study area illustrating the patchy nature of advance amabilis fir stocking.

Fig. 5 Typical overstocked clumps of advance amabilis fir with high mutual competition.

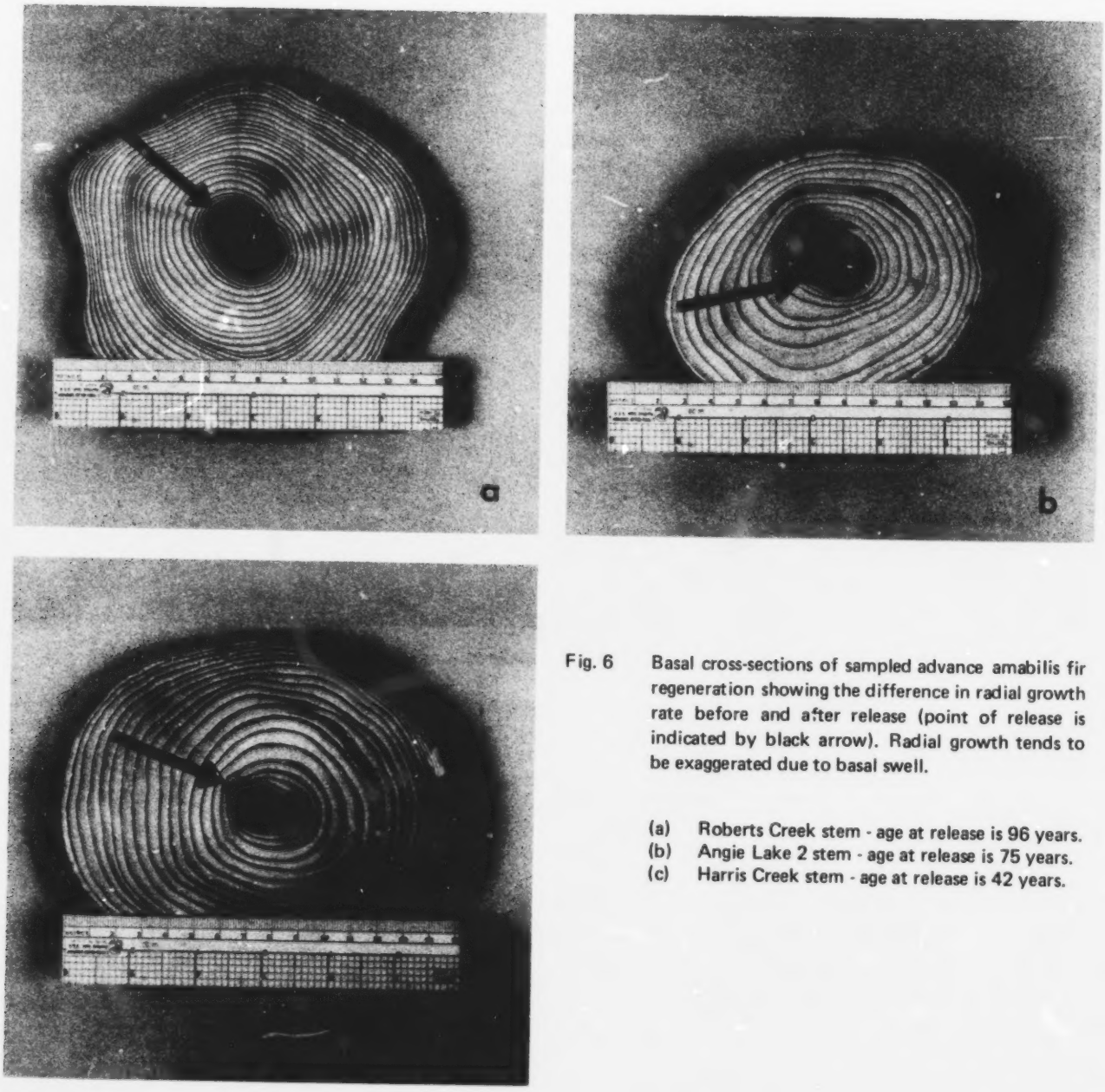

Fig. 6 Basal cross-sections of sampled advance amabilis fir regeneration showing the difference in radial growth rate before and after release (point of release is indicated by black arrow). Radial growth tends to be exaggerated due to basal swell.

(a) Roberts Creek stem - age at release is 96 years.
(b) Angie Lake 2 stem - age at release is 75 years.
(c) Harris Creek stem - age at release is 42 years.

A relationship between age at release and stem form existed for only two study areas. This may suggest that the size and age of advance amabilis fir regeneration affects the form of the stem. That is, the older the stem, the larger the stem, and the larger the stem, the more susceptible it is to factors that result in stem deformities after release, such as logging damage. The relationship between stem form, stem size at release and stem damage will be elaborated more fully in the discussion on pathological results.

No direct relationship exists between age at release and growth response rate. This fact is illustrated by Figure 6, which shows the growth response of three advance regeneration stems with a wide range of ages at release. It appears that stem age alone does not determine the ability of an advance growth stem to respond after release.

Multiple regression analysis was applied to the study data in an attempt to identify the most significant factors affecting the growth of advance regeneration after release. Stepwise elimination techniques identified the most significant factors in each study area as being stem competition and stem size at release. These variables, however, explained only a small portion of the regression on growth (R^2=0.1-0.5), with considerable variation left unexplained. Better regression fit was achieved for breast-height and basal diameter growth than for height growth. When the analysis was performed on individual subarea data, higher R^2 values (0.3-0.6) were attained. This suggests that possibly site quality constitutes a considerable portion of the otherwise unexplainable variation in the study area regressions. The most significant independent variables were the same as those in the area calculations; that is, competition and size at release. In all regressions, age at release was eliminated early in the stepwise procedure, again indicating the relative insignificance of this variable in explaining post-logging growth response.

Fig. 7 Height growth response of advance amabilis fir stem at Thistle Mine 1 study area, after logging in 1967. Tree is held at the point of height-at-release. Stem age at release is 54 years.

Study Area	Subarea	Mean annual Height Growth (m)	Mean Annual Basal Diameter Growth (cm)	Mean Annual Breast Height Diam.Growth (cm)
Harris Creek	2-Moist habitat	0.28	0.58	0.45
Harris Creek	3-Dry habitat	0.16	0.36	0.30
Roberts Creek	2-Moist habitat	0.43	0.86	0.72
Roberts Creek	1-Dry habitat	0.38	0.72	0.62

Table 3 Comparisons of mean annual growth rates between subareas of two study areas based on relative moisture status. Differences between subareas within areas are significant, based on Behrens - Fisher test (Snedecor, 1959).

2. Decay Hazard Analysis

a) Logging Damage and Decay - a total of 145 trees out of 703 samples from 11 study areas had logging injuries (Table 4). This represented an average incidence of damage of 20.6%. Broken tops accounted for 24% of the injuries, whereas 76% were various types of stem wounds, including scalps and deep gouges. Stem wounds, on the average, ranged from 30 to 90 cm in length and were likely caused by falling and yarding phases of the logging operation. The average basal diameter at release of injured trees was 2.0 cm compared to 1.9 cm for all trees sampled. Frost damage was infrequent.

The incidence of logging damage was appreciably greater on the recently logged areas than on the earliest logged areas. This was due to scars, especially smaller ones, being increasingly more difficult to detect by external stem characteristics with increasing numbers of years after logging. For this reason, the maximum incidence of wounding (26 to 30%) (Table 4) for the more recently logged Thistle Mine study areas provides a more realistic estimate of logging damage to surviving advance regeneration than the average for the entire sample. These damage estimates apply only to trees surviving the logging operation and provide no indication of outright understory mortality caused by logging. The occurrence of top and bole damage varied considerably between the study areas, likely reflecting differences in topography, method of logging and machinery used, as well as changes in utilization methods between 1940 and 1970.

Stem dissection showed that about 70% of the injured trees had hidden defect in the form of stain or decay. Based on the entire sample, however, only about 13% of the stems contained hidden defect associated with injuries (Table 5). Table 5 shows the incidence of hidden defect and viable decay infections in relation to the occurrence of "open" and "closed" wounds. Decay culture analysis results (based on 629 isolation attempts) indicated that only 13 of the total trees sampled in 11 study areas contained active decay infections, all associated with open logging wounds. This represents an incidence of only 1.8% for all trees sampled, and 13.7% in terms of injured trees with hidden defect (Tables 4 and 5). Over 85% of the hidden defects were not associated with viable decay fungi at the time of sampling. This can be attributed partly to the absence of active decay infections in the closed or healed injuries that predominated in the wound samples. Nevertheless, over half of the open wounds were also free from decay, indicating that many of the observed defects were not of fungal origin, and would not constitute a threat to the future crop. Other defects were of fungal origin, but were not caused by wood destroying organisms.

Haematostereum sanguinolentum, one of the most common wound parasites attacking Abies species in B.C., was responsible for 8 of the 13 active decay infections. Other fungi involved in the remaining infections were Poria monticola, Lenzites saeparia and Amylostereum chailletii. One active infection of Echinodontium tinctorium was found associated with an open wound in the Angie Lake 2 study area.

Essentially, these results are in agreement with Aho (1960), who found the decay hazard to be virtually non-existent in the small diameter amabilis fir advance regeneration that he sampled 9 years after logging in the Gifford Pinchot National Forest in Washington. In the present study, only 1.8% of the trees sampled up to 30 years after logging had active decay infections, nearly all in the large diameter stems (avg 6.8 cm in basal diameter at release). In both studies, the characteristics of advance regeneration that contributed most to the low wound-associated decay hazard were the predominance of small diameter stems left after logging, and the resulting post-logging accelerated diameter growth. Small advance regeneration stems can only endure minor injury if they are to survive logging. This fact, together with rapid wound healing after release, effectively minimizes decay development which is confined to tissues present at the time of the injury. Once the wound is fully healed, decay development is stopped completely.

Table 6 shows the frequency of logging damage and viable decay infection in relation to basal stem diameter at release ($<$ or $\geq$ 2.5 cm). Approximately four times the frequency of logging injuries occurred to stems with large basal diameters at release (50.6%) compared with smaller stems (12.0%). Also, the incidence of active decay infections in large injured stems was almost five times as great (14.1%) compared with the smaller stems (3.0%). These results suggest that for surviving advance regeneration stems, the larger the stem, the higher the damage risk; also, the larger the stem, the greater the decay hazard associated with logging injuries. The latter statement is due to the relationship between size of injury and rate of healing process mentioned previously. Large advance regeneration stems can sustain large wounds and survive; these large wounds may remain unhealed for extended periods of time, increasing the risk of decay development. Small advance regeneration stems, in comparison, are more desirable from the standpoint of lower defect and decay risk. From a practical forestry standpoint, however, the very low incidence of decay found in the study precludes any serious concern for wound-associated decay hazard.

b) Present and Potential Threat by the Indian Paint Fungus - studies by Etheridge et al. (1972) on the mode of Indian paint fungus attack on western hemlock demonstrated that entry courts for this fungus were small diameter branch stubs, rather than stem injuries as previously believed. They demonstrated that the duration of the healing process

Table 4. Incidence of logging injuries, and presence of hidden defect and active decay infections associated with logging wounds.

Study Area	Date of Logging	Sample Size	Injured Trees	Hidden Defect Associated with Wounds	Active Decay Infections
Gordon River 1 & 2	1958 (avg)	49	9(18.4%)	6(12.2%)	2(4.1%)
Harris Creek	1954	111	23(20.7%)	16(14.4%)	2(1.8%)
Thistle Mine 1	1967	72	22(30.5%)	6(8.3%)	0(0.0%)
Thistle Mine 2	1964	60	16(26.6%)	8(13.3%)	1(1.7%)
Roberts Creek	1945	66	8(12.1%)	3(4.5%)	2(3.0%)
Popkum 1 & 2	1947 (avg)	53	12(22.6%)	9(17.0%)	3(5.7%)
Angie Lake 1	1959	80	16(20.0%)	14(17.5%)	0(0.0%)
Angie Lake 2	1960	144	30(21.0%)	28(19.6%)	1(0.7%)
Lyon Lake	1953	68	9(13.2%)	5(7.4%)	2(2.9%)
Totals		703	145(20.6%)	95(13.5%)	13(1.8%)

Table 5. Incidence of active decay infections in relation to hidden defect, for all logging wounds, and in association with "open" and "closed" logging wounds.

Study Areas	All Wounds		Open Wounds		Closed Wounds	
	With Hidden Defect	With Active Decay	With Hidden Defect	With Active Decay	With Hidden Defect	With Active Decay
Gordon River 1&2	6	2(33.3%)	3	2(66.7%)	3	0(0.0%)
Harris Creek	16	2(12.5%)	5	2(40.0%)	11	0(0.0%)
Thistle Mine 1	6	0(0.0%)	4	0(0.0%)	2	0(0.0%)
Thistle Mine 2	8	1(12.5%)	3	1(33.3%)	5	0(0.0%)
Roberts Creek	3	2(66.7%)	2	2(100.0%)	1	0(0.0%)
Popkum 1&2	9	3(33.3%)	3	3(100.0%)	6	0(0.0%)
Angie Lake 1	14	0(0.0%)	0	0(0.0%)	14	0(0.0%)
Angie Lake 2	28	1(3.8%)	6	1(16.6%)	22	0(0.0%)
Lyon Lake	5	2(40.0%)	3	2(66.7%)	2	0(0.0%)
Totals	95	13(13.7%)	29	13(44.8%)	66	0(0.0%)

Table 6. Incidence of logging damage and active decay infections associated with logging wounds, in relation to basal diameter at release.

Study Area	Sample Size	All Sample Trees		All Sample Trees With Logging Damage		All Sample Trees With Active Decay	
		< 2.5 cm	≥ 2.5 cm	< 2.5 cm	≥ 2.5 cm	< 2.5 cm	≥ 2.5 cm
Gordon River 1 & 2	49	39	10(20.4%)[1]	5(12.8%)[2]	4(40.0%)[3]	1(2.6%)[2]	1(10.0%)[3]
Harris Creek	111	86	25(22.5%)	11(12.8%)	12(48.0%)	0(0.0%)	2(8.0%)
Thistle Mine 1	72	68	4(5.5%)	17(25.0%)	4(100.0%)	0(0.0%)	0(0.0%)
Thistle Mine 2	60	43	17(28.3%)	6(13.9%)	10(58.8%)	1(2.3%)	0(0.0%)
Roberts Creek	66	51	15(22.7%)	0(0.0%)	8(53.3%)	0(0.0%)	2(13.3%)
Popkum 1 & 2	53	21	32(60.4%)	0(0.0%)	12(37.5%)	0(0.0%)	3(9.4%)
Angie Lake 1	80	67	13(16.3%)	12(17.9%)	4(30.8%)	0(0.0%)	0(0.0%)
Angie Lake 2	144	118	26(18.1%)	13(11.0%)	17(65.4%)	0(0.0%)	1(3.8%)
Lyon Lake	68	56	12(17.6%)	2(3.6%)	7(58.3%)	0(0.0%)	2(16.6%)
Totals	703	549	154(21.9%)	66(12.0%)	78(50.6%)	2(0.4%)	11(7.1%)

[1] Percentage of total trees sampled

[2] Percentage of stems < 2.5 cm

[3] Percentage of stems ≥ 2.5 cm

for these stubs determined their suitability as entry courts. Long periods of suppression, with the associated depressed radial increment and callus tissue development, increased the likelihood of infection.

Based on these findings, concern was expressed over the potential for Indian paint fungus attack on advance amabilis fir regeneration, particularly due to the inherently long periods of suppression it undergoes. Infection of an entry court during suppressed growth does not necessarily result in immediate decay development, since the Indian paint fungus often becomes dormant soon after entry in the stem. The presence of these dormant infections could pose a threat to advance amabilis fir regeneration, however, since stem injuries received during clearcutting of the overstory stand can reactivate the dormant infections in the immediate proximity of the injury and initiate the decay process.

The advance amabilis fir sampled during the 1974 field season were studied in order to characterize the nature of their small (less than 5 mm in diameter) branch stubs and to determine the susceptibility of the species to infection. Etheridge and Craig (1975) reported that suitable entry courts for the fungus were present on advance amabilis fir regeneration only after approximately 60 years of suppression and that the percentage of stems over 60 years of age at release would be a relative measure of the potential susceptibility of a stand. Applying these criteria, the study areas were grouped into relative hazard categories (Table 7).

The Popkum study areas fell into the highest relative risk category, with about twice the frequency of older stems compared with other areas.

Survey results from all study areas revealed only one active decay by the Indian paint fungus in a tree from Angie Lake 2 study area. This tree had grown for 104 years under suppression, reaching a height of 1.5 m by 1960 when the area was logged. The infection had originally been dormant, but was reactivated by a logging injury. It is significant, however, that no other active infections were found in the advance amabilis fir regeneration of either of the Angie Lake areas, since the overmature amabilis fir and western hemlock in the adjacent unlogged stands were heavily infected with Indian paint fungus This heavy spore concentration would have maximized the opportunity for infection of the advance regeneration understory.

Supplementary sampling (based on 551 isolation attempts) of small embedded branch stubs considered to be potential infection courts showed that the fungus occurred as two dormant infections in one tree from the Popkum 2 study area. This tree was the oldest sampled (155 years at release) and the two dormant infections were estimated to have been initiated in branch stubs 65 and 85 years ago. No dormant infections were found in the Angie Lake study areas and it is assumed to be due to the relatively young average age of the advance regeneration.

The results of the study indicate that although the incidence

Table 7. Percentage of advance amabilis fir regeneration aged 60 years or older at time of release. Figures followed by a letter in common are not significantly different (P=0.05)

Study Area	Sample Size	Number and Percent (in brackets) of Stems Older than 60 years	
Thistle Mine 1	72	6	(8.3) a
Thistle Mine 2	60	5	(8.3) a
Angie Lake 2	144	23	(15.9) ab
Gordon River 1 & 2	49	8	(16.3) ab
Angie Lake 1	80	15	(18.7) ab
Harris Creek	111	24	(21.6) b
Roberts Creek	66	16	(24.2) b
Lyon Lake	68	17	(25.0) b
Popkum 1 & 2	53	22	(41.5) c

of decay and dormant infection by the Indian paint fungus is very low, there is a potential threat to amabilis fir under certain conditions. For example, infection courts are formed in relatively large numbers in suppressed advance amabilis fir between 50 and 60 years of age and the heartrot hazard in stands increases with increasing proportions of this age class or older. As previously indicated, however, the age of advance regeneration is not directly correlated with any easily identified external characteristic such as height or diameter and, therefore, cannot be realistically assessed by survey. However, since most of the serious injuries occurred in trees of large basal diameter, and wounding is necessary to reactivate dormant infections, it would seem safe to leave advance amabilis fir to at least a 5-cm basal diameter limit (at release), with little or no threat from the Indian paint fungus.

CONCLUSIONS

1. Age and size of advance amabilis fir regeneration varies considerably, even within the same stand. The age of advance regeneration cannot accurately be estimated by height or diameter at release, due to variations in suppressed growth rate. The only accurate method of age assessment is by destructive sampling and growth ring analysis of the basal stem section.

2. The postlogging stocking of advance amabilis fir regeneration is usually clumpy, due to pre-logging distribution or mortality caused by logging damage. Density within clumps is often high, creating high mutual competition. In many cases, additional natural regeneration or fill-planting will be required to bring stocking levels up to an acceptable standard. Density control within clumps is often necessary to reduce competition and maximize growth response.

3. The stem form of advance regeneration at release is often poor, due to growing conditions in the understory. Most minor deformities, however, are quickly outgrown as the stem accelerates its growth rate. A small percentage of stems are seriously damaged by logging, resulting in severe deformities. Early removal of these stems is desirable from a silvicultural standpoint.

4. Diameter growth response delays are commonly one or two full years after the year of logging, while noticeable height growth response may require an additional several years.

5. Site quality determines to a large degree the level of growth response in advance amabilis fir regeneration. Poor response growth and generally poor health are common in advance growth on sites where moisture stress situations exist.

6. Stem competition adversely affects the level of response growth in dense clumps of advance regeneration and makes spacing a desirable prescription.

7. Stem size affects response growth, in that larger stems are less sensitive to mutual competition in clumps than are smaller stems.

8. Approximately 20% of the advance amabilis fir stems in a stand suffer some form of injury, largely the result of clearcut logging damage.

9. Large diameter stems (basal diameter> 2.4 cm (i.b.)) are more susceptible to logging damage and sustain more serious injury than smaller stems.

10. A low incidence of decay is common in released stands of advance regeneration. Active decay infection is restricted to "open" wounds and stems of large (> 2.4 cm (i.b.)) basal diameter at release. The most common wound parasite associated with these infections is Haematostereum sanguinolentum.

11. After accelerated growth response, small wounds (or wounds on small diameter stems) heal, or "close" over rapidly, and prevent or eliminate decay infections.

12. The incidence of decay by the Indian paint fungus was very low, or nonexistent, in the areas studied. The heartrot hazard, however, increased with the percentage of stems 60 years of age or greater at time of release. Diameter at time of release is not an accurate predictor of age; however, advance amabilis fir stems less than 5 cm (roughly 2 m in height) in basal diameter at release can be considered safe from the threat of the Indian paint fungus.

RECOMMENDATIONS

Based on the findings of this report, some general silvicultural recommendations are presented for the management of advance amabilis fir regeneration. Two major requirements must be met before consideration may be given to the use of advance growth in reforestation.

1. The site must be assessed for its suitability in supporting the growth of amabilis fir. Very dry sites having moisture deficit problems (due to edaphic or climatic factors) will not support satisfactory amabilis fir growth response and should not be selected for advance regeneration management. The presence of advance growth in the understory on such a site before logging is not reason enough to consider it as suited to the growth of amabilis fir after logging.

2. A suitable level of understory stocking by advance regeneration before logging is required to ensure adequate stocking after logging and associated mortality. A pre-logging advance regeneration survey is required to obtain this information to determine reforestation strategy. Only advance growth less than 2 m in height should be tallied in such a survey. All but the most severely deformed stems in this size class should be considered as acceptable regeneration. Stems larger than 2 m should not be considered as acceptable, since it is doubtful that many trees of this size class would survive a close utilization logging operation. If the pre-logging stocking level of the preferred size class is below a minimum suitable level, artificial regeneration will be required. This minimum pre-logging stocking level is presently an unknown factor and will only be determined through experience and further study.

If the above requirements are met following a pre-logging survey, the health and vigor of the advance amabilis fir regeneration may be maximized by removing all trees greater than 2 m in height (5 cm basal diameter) during the falling operation in the overstory stand. Large, vigorous seedlings of a complimentary species suited to the site should be inter-planted in understocked areas as soon as possible after the logging operation. Juvenile spacing should also be carried out after 10 to 15 years to reduce clumpiness and eliminate badly deformed stems.

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APPENDIX I

STUDY AREA DESCRIPTIONS

1. **Gordon River** - the Gordon River study area is situated southwest of Gordon River camp on truck road five (latitude 48°45' 30" N., longitude 124° 21' W.). The study area encompasses approximately 23 hectares, most of which was clearcut during April to October of 1959. A small portion, however, was logged in October 1956. Although nearby clearcuts have been slashburned, the study area has remained unburned since logging.

The study area lies within the Pacific Silver Fir-Western Hemlock subzone of the Coastal Western Hemlock biogeoclimatic zone (Krajina, 1969), at an elevation of between 450 to 600 m. The underlying bedrock is largely andesitic, belonging to the Bonanza Volcanics formation (Muller, 1971). Soils on the slopes are mainly medium textured glacial till and coarse colluvium, with colluvium and recent alluvium in the valley bottom. Situated in a narrow tributary valley of the Gordon River drainage, the clearcut covers two steep, opposite facing slopes, as well as the relatively flat bottom land between them. Three transects were made, one on each of the three site types, or subareas. For simplicity, each subarea will be described separately.

a) Subarea 1 - site, or subarea 1 is situated on a steep 60 to 90% slope lying between 450 and 600 m in elevation with an aspect of N. 20°E. The soils are shallow and bedrock outcrops on the slopes are common. Regeneration, both advance and postlogging natural, is listed below in order of occurrence:

Tsuga heterophylla - 90% (due largely to the proximity of a nearby seed source).

Abies amabilis - 10%

Major plant species found on the transect are listed below in order of their relative occurrence.

Achlys triphylla
Maianthemum dilatatum
Polystichum munitum
Blechnum spicant
Vaccinium sp.

Other species occurring less frequently are Rubus spectabilis, Rubus parviflorus and Oplopananx horridus.

b) Subarea 2 - subarea 2 is situated on a steep (40-80%) S.80°W. facing slope between 500 to 600 m in elevation. The soils are similarly shallow with rock outcrops. The order of occurrence of major coniferous regeneration species is as follows:

Abies amabilis	50%
Tsuga heterophylla	30%
Thuja plicata	15%

Minor vegetation species are listed below in order of their relative occurrence:

Gaultheria shallon
Vaccinium sp.
Berberis nervosa

Also occurring, but less frequently, are Achlys triphylla, polystichum munitum and blechnum spicant. These species are generally restricted to the more moist, shaded microsites.

c) Subarea 3 - subarea 3 is situated on the valley floor between 485 to 550 m in elevation. The average slope of this site is 15%, with a N.40°W aspect. The soils are deep, moist and of a colluvial-alluvial origin. Dominant species of regeneration are Tsuga heterophylla and Abies amabilis with minor Thuja plicata. The most abundant minor vegetation species present are Vaccinium sp. and Rubus spectabilis. On the wetter microsites, Polystichum munitum, Blechnum spicant and Tiarella trifoliata are common.

Due to the difference in dates of logging, the Gordon River site was subdivided into two separate study areas: Gordon River 1, clearcut in 1959, and Gordon River 2, a very small portion of the overall area that was logged in 1956.

2. **Harris Creek** - The Harris Creek study area is situated northeast of Port Renfrew on Harris Creek branchline 1200 (latitude 48°41'30"N., longitude 124°12'W.) The study area encompasses approximately 20 hectares, clearcut in 1953 and 1954. Except for occasional spot burning on landings, no broadcast burning was carried out on the study area.

The study area lies within the Pacific Silver Fir-Western Hemlock biogeoclimatic subzone between 560 and 620 m in elevation. The underlying bedrock is generally limestone, calcareous siltstone and greywacke of the Quatsino formation (Muller, 1971). This formation contacts the Karmutsen Volcanic formation (which includes basalts, pillow and flow lavas and breccias) in the vicinity of the study area; consequently, the glacial tills in the area may be a mixture of both parent bedrock types. The topography is characterized by a gentle complex slope of between 10 to 24%. Three transects were made in the area, one in each of three site types, or subareas.

a) Subarea 1 - subarea 1 is situated on the downslope side of a road that bisects the study area. The average slope is 10%, with a gently rolling topography and a northwest aspect. Moist microsites and deep soils are common in the concave portions, while shallow soils and bedrock outcrops are common on the convex portions of the subarea. Major regeneration species are listed below in their relative order of dominance:

Tsuga heterophylla	40%
Abies amabilis	30%
Thuja plicata	25%

Pseudotsuga menziesii is present only as a minor species component. Minor vegetation species found on the transect are given below in order of dominance:

Vaccinium sp.
Gaultheria shallon
Linnaea borealis
Achlys triphylla
Cornus canadensis

Other species occurring less frequently and in the moist microsites are Smilacina amplexicaulis, Polystichum munitum, Adiantum pedatum, Blechnum Spicant and Gymnocarpium dryopteris.

b) Subarea 2 - subarea 2 is situated above the road and has a higher average slope of 20%, with an overall northwest aspect. The subarea is dissected by three east-west trending drainage channels, with accompanying ridges some 10 to 12 m in relief above the stream beds. The survey transect ran across these ridges and depressions and, as a result of the concave - convex nature of the topography, aspects changed from southwest to northeast on each side of the ridges, but displayed the overall northwest aspect in the concave drainage depressions themselves. Soil depths also varied, with shallow soils on the ridge crests, gradually deepening down their sides, and deepest in the concave areas. Regeneration species are the same as site 1; however, Abies amabilis is present in larger numbers than Tsuga heterophylla. Pinus monticola is also present as a minor species component. Minor vegetation was also similar to site 1; that is, Vaccinium sp., Gaultheria shallon and Berberis nervosa on the drier sites, and Polystichum munitum, Maianthemum dilatatum, Gymnocarpium dryopteris and Veratrum escholcholtzii on the moist concave sites.

c) Subarea 3 - subarea 3 is situated on the downslope side of the road. Relief is low, with a gentle overall slope of 10 to 15%. Aspects vary from northwest to southwest, but due to the low relief and slope, exposure to insolation is high. Elevations range from 500 to 600 m. There were no indications of bedrock outcrops on subarea 3, which suggests that the soils were at least moderately deep. Dominant regeneration species were Abies amabilis, Tsuga heterophylla, and Thuja pilcata, with Pseudotsuga menziesii and Chamaecyparis nootkatensis as minor species. Minor vegetation species found along the transect are listed below in order of dominance:

Gaultheria shallon
Vaccinium sp.
Linnaea borealis
Achlys triphylla
Cornus canadensis

Other less frequently occurring species include Berberis nervosa, Rubus parviflorus, Maianthemum dilatatum, Blechnum spicant and Tiarella trifoliata.

3. Thistle Mine - the Thistle Mine area is situated southeast of Port Alberni on the Thistle Mine road (latitude 49°07' N., longitude 124°39' W.). It includes two separate clearcut blocks, each of which will be considered as a separate study area: Thistle Mine 1 and Thistle Mine 2.

Thistle Mine 1 study area encompasses approximately 6 hectares which were clearcut in 1967. The area lies within the Pacific Silver Fir-Western Hemlock biogeoclimatic subzone between 760 to 880 m in elevation. The topography is characterized by a simple concave slope of 55 to 80%, with an aspect of N.20°E. The underlying bedrock of the study area is a member of the Sicker Volcanics (Muller, 1971) formation, composed largely of meta-andesites, dacites and breccias. In close proximity to the study areas, however, lie bedrocks of the Island Intrusions, Buttle Lake Limestones, Sicker Sediments and Karmutsen Volcanics. It is highly probable that the glacial tills of the area are composed of mixtures of all these bedrocks. The soils of Thistle Mine 1 area are largely composed of glacial till and colluvium and are generally quite shallow, with frequent bedrock exposures. Due to the overall homogeneity of slope and site characteristics, no subdivision into subareas was made.

The major regeneration species are Abies amabilis, followed by Tsuga heterophylla. Minor vegetation species are listed below in order of dominance:

Vaccinium sp.
Rubus spectabilis
Tiarella trifoliata
Blechnum spicant
Achlys triphylla

Less frequently occurring are Athyrium felix-femmina, Sambucus racemosa and Rubus parviflorus.

Thistle Mine 2 study area encompasses approximately 8 hectares that were clearcut in 1964. The site lies between 610 and 760 m in elevation, with a northerly aspect. The soils and bedrock are similar to Thistle Mine 1 area, although rock outcrops are less frequent.

Regeneration species are the same as Thistle Mine 1, with the addition of Thuja plicata as a minor species component. The minor vegetation species are listed in order of dominance:

Vaccinium sp.
Achlys triphylla
Rubus spectabilis
Polystichum munitum
Lycopodium clavatum

Occurring less often are Rubus parviflorus, Cornus canadensis and Tiarella trifoliata.

4. **Roberts Creek** - the Roberts Creek study area is situated northeast of Roberts Creek on the Wilson Creek East main road, just west of Mt. Elphinstone (latitude 49°29'N., longitude 123°36'W.). The study area encompasses approximately 40 hectares that were clearcut in 1945. It lies within the Pacific Silver Fir - Western Hemlock biogeoclimatic subzone at an elevation of between 760 and 790 m. The terrain is rolling, with a slope of 0 to 5%. The underlying bedrock of the area is granitic, largely granodiorite and quartz diorite. The area is covered with deep glacial till deposits from which deep soils of moderate to coarse texture have developed.

Two subareas, or site types were recognized, one on each side of the bisecting access road. Subarea 1, on the upslope side of the road, tended to be convex, whereas subarea 2, on the lower side of the road, had numerous drainage channels and depressions that tended to make it more moist and concave.

The regeneration species of both sites are as follows:

Tsuga heterophylla	65%
Abies amabilis	35%

Minor vegetation species found in subarea 1 are listed in order of dominance:

Vaccinium sp.
Pteridium aquilinum
Rubus spectabilis

Other species occurring less frequently in subarea 1 are Athyrium felix-femina, Polystichum munitim and Menziesia ferruginia.

On subarea 2, the same species are present, except for Pteridium aquilinum.

5. **Popkum** - the Popkum area is situated near Bridal Veil falls and the town of Popkum, and lies between 940 and 1090 m in elevation on the northwest facing slopes of the Fraser Valley. The study area, encompassing approximately 20 hectares, was clearcut on two different dates. A small 5 hectare portion was logged in 1944, while logging of the remainder occurred in 1947. Each of these portions has been considered as a separate study area; the larger portion logged in 1947 is designated Popkum 2 study area, the smaller portion as Popkum 1 study area.

The two study areas lie within the Pacific Silver Fir - Western Hemlock biogeoclimatic subzone. The underlying bedrock is metamorphic pelite of the Chilliwack formation, as well as basalt. Soils are derived from glacial-till and colluvium and tend to be shallow and fine textured. Slopes vary from 5 to 70%, and bedrock outcrops are common. The major regeneration species in Popkum 2 study area are listed in order of occurrence as follows:

Abies amabilis	50%
Tsuga heterophylla	35%
Thuja plicata	10%

In Popkum 1, however, stocking is largely made up by small western hemlock saplings. Large advance amabilis fir stems account for only 25% of the regeneration. Both subareas have the following minor vegetation species, listed in order of dominance:

Rubus spectabilis
Rubus parviflorus
Athyrium felix-femina
Rubus pedatus
Oplopananx horridus is also present on very moist microsites.

6. **Angie Lake** - the Angie Lake study area is situated approximately 20 miles west of Menzies Bay, near the junction of Grilse Creek and the Salmon River (latitude 50°04'N., longitude 125°49'W.). The study area encompasses two separate clearcut openings, each of which will be considered as a separate study area.

Angie Lake 1 study area is situated on a complex 15 to 50% slope lying between 600-670 m in elevation, with an aspect of S. 20°E. The glacial till soils are derived from the basaltic bedrock of the Karmutsen Volcanics Formation (Muller, 1971) and are relatively fine textured. Soil depth is quite variable on the complex topography, ranging from deep, well-drained phases on the lower slopes to poorly drained lithic phases on several small, bedrock controlled terraces.

No distinct variation in site was observed; therefore, no subdivision of the area into subareas was made. The study encompasses approximately 25 hectares, clearcut in 1959. Regeneration species are listed in order of occurrence as follows:

Tsuga heterophylla	40%
Abies amabilis	28%
Pseudotsuga menziesii	17%
Thuja plicata	15%

Major plant species found on the transects are also listed below in order of their relative occurrence:

Vaccinium sp.
Berberis nervosa
Linnaea borealis
Gaultheria shallon

Other species occurring less frequently include Cornus canadensis, Achlys triphylla and mosses.

Angie Lake 2 study area is also situated on a complex topography consisting of a slope unit and a lower bench. These two components represent two distinct site types, and were treated as separate subareas.

Subarea 1 is characterized by a simple 30-60% slope, and lies between 760 to 820 m in elevation with a S.20°E aspect. Soils are relatively deep and well drained, with similar texture as Angie Lake 1 area. Shallow soils and rock outcrops are present, but infrequent. The subarea was clearcut in 1960, and is approximately 8 hectares in size. Regeneration species are listed below in order of their relative occurrence:

Abies amabilis	80%
Tsuga heterophylla	18%

Very minor Thuja plicata was also present, but was of little importance. Major plant species found on transects are listed in order of relative occurrence as follows:

Cornus canadensis
Vaccinium sp.
Linnaea borealis
Blechnum spicant

Other less frequently occurring species are Berberis nervosa, Achlys triphylla, Polystichum munitum and Chimophylla umbellata.

Subarea 2 of Angie Lake 2 study area is characterized by a bench of 0-5% slope. It lies at 760 m in elevation, with a neutral to S.20°E aspect. Soils on this subarea are generally more shallow than subarea 1 and have frequent bedrock controlled small ridges and depressions. The subarea encompasses approximately 5 hectares, clearcut in 1960. Regeneration species are Abies amabilis and Tsuga heterophylla in approximately equal proportions. Other species include Pseudotsuga menziesii, Thuja plicata and Chamaecyparis nootkatensis, but these are infrequently occurring. Major plant species found in subarea 2 are listed in order of abundance as follows:

Vaccinium sp.
Linnaea borealis
Cornus canadensis
Chimophila umbellata
Blechnum spicant

7. Lyon Lake - the Lyon Lake study area is situated 9 miles north of Halfmoon Bay on the Sechelt Peninsula (latitude 49°38'N., longitude 123°54'W). The study area encompasses approximately 20 hectares of rolling plateau-like topography, and lies at 900 m in elevation on a northwest aspect. Clearcutting of the area occurred in 1953. The underlying bedrocks are similar to Roberts Creek study area, although soil depth varies considerably from deep, poorly drained depressional phases to shallow, lithic soils on exposed convex surfaces. The area is relatively homogeneous, however, and no subarea differentiation was carried out. Regeneration species in the Lyon Lake study area are listed below:

Tsuga heterophylla	46%
Abies amabilis	40%
Tsuga mertensiana	14%

The major plant species in the study area was found to be Vaccinium sp. This was due to the early date of sampling, which was carried out prior to the emergence of many herbs.

APPENDIX II. Simple Correlation Analyses Results

* - significant to 99% probability level

- significant to 95% probability level

Correlation Variables		Gordon River 1	Harris Creek	Thistle Mine 1	Thistle Mine 2	Roberts Creek	Popkum 1	Popkum 2	Angie Lake 1	Angie Lake 2	Lyon Lake
Height Growth Response	Age at Release										-0.295
Height Growth Response	Ht at Release										
Height Growth Response	Bas. D. at Release					-0.301					
Height Growth Response	Competition No.		-0.200		-0.346*	-0.342*			-0.259	-0.381*	
Height Growth Response	Competition Class					-0.433*			-0.240	-0.392*	
Height Growth Response	Form Class					-0.330*		-0.437	-0.351*	-0.273	
Bas. D. Growth Response	Age at Release									+0.297	
Bas. D. Growth Response	Ht at Release	+0.432*		+0.312*					+0.432*	+0.472*	
Bas. D. Growth Response	Bas. D. at Release	+0.310*				-0.264*			+0.226	+0.270	
Bas. D. Growth Response	Competition No.	-0.377*	-0.358*		-0.582*	-0.523*	-0.541*	-0.455	-0.328*	-0.389*	-0.321*
Bas. D. Growth Response	Competition Class		-0.316*		-0.521*	-0.654*	-0.475*	0.558*	-0.362*	-0.420*	-0.267
Br. Ht. D. Growth Resp.	Age at Release			+0.304*				+0.405*	+0.242	+0.403*	
Br. Ht. D. Growth Resp.	Ht. at Release	+0.486*	+0.299*	+0.668*	+0.330*	+0.264			+0.476*	+0.488*	
Br. Ht. D. Growth Resp.	Bas. D. at Release	+0.396*	+0.348*	+0.505*	+0.378*					+0.460*	
Br. Ht. D. Growth Resp.	Competition No.		-0.288*		-0.453*	-0.568*		-0.560*	-0.235	-0.326*	
Br. Ht. D. Growth Resp.	Competition Class		-0.266*		-0.316	-0.654*		-0.615*	-0.222	-0.306*	
Age at Release	Ht. at Release	+0.636*	+0.564*	+0.663*	+0.672*	+0.317*	+0.656*	+0.634*	+0.667*	+0.700*	+0.920*
Age at Release	Bas. D. at Release	+0.695*	+0.676*	+0.700*	+0.692*	+0.430*	0.499	+0.725*	+0.260	+0.815*	0.931*
Age at Release	Form Class					+0.390*		+0.412*			+0.463*
Basal D. at Release	Height at Release	+0.888*	+0.804*	+0.827*	+0.819*		+0.606*	+0.854*	+0.269	+0.818*	+0.973*